

NOTES ON THE GEOLOGY OF THE ISLAND OF ANTIGUA.

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During parts of July and August, 1913, I made a visit to the island of Antigua in the hope of finding a place where the Oligocene fauna of the rocks of the island would be in a condition to permit of extensive collection. I was in hopes that the fossils would be found in incoherent or soft material as I found them at Panama and as Gabb found them in Santo Domingo. With this in view, I made a rather close examination of practically all places from which fossils had been obtained that were known to the local naturalists of the island. Three weeks were spent on the island and many localities were visited. In this search I was aided by Mr. W. R. Forrest, a resident of St. John's, and by Mr. H. A. Tempany, Superintendent of Agriculture of the Leeward Islands, also of St. John's. To both of these gentlemen I was indebted for many courtesies, and each of them acted as my guide to localities on several occasions. I was not successful in finding any place where the fossiliferous deposits were in a condition permitting of the ready extraction of the specimens, although from what I was able to observe the fauna represented is a large one.

The island of Antigua lies in latitude 17° to $17^{\circ} 10'$ north and between longitude $61^{\circ} 40'$ and $61^{\circ} 55'$ west of Greenwich. It lies in the outer row of calcareous islands in the Leeward group, which comprises eastern Guadeloupe (Grande Terre), Marie Galante, Antigua, Barbuda, St. Bartholomew, St. Martin, Anguilla and Sombbrero. It measures about $9\frac{1}{2}$ miles from north to south and 12 miles from east to west, with a coast-line of some 70 miles and an area of 108 square miles. The shape of the island is roughly trapezoidal or nearly triangular, the coast-line is deeply indented by bays on the northeast and east sides, with Willoughby Bay at the southeast corner, English and Falmouth Harbors on the south coast, and Morris Bay, Five Islands Harbor and St. John's Harbor on the west side. Numerous smaller bays and roadsteads have received names and are used by the coasting boats calling at points along the south and west shores. The surface of the island is roughly divided into

three regions by the Central Plain, which extends diagonally across the island from St. John's Harbor in the northwest to Willoughby Bay in the southeast; a region that is generally flat and at no great elevation above the sea, but with several hills rising from the plain to an altitude of 200-350 feet. To the northeast of this Central Plain is the marl or limestone belt, a region of undulating land at a somewhat higher elevation than the Central Plain (150-200 feet), with hills rising to 250 up to 350 feet; and in the southeast, in St. Philip's Parish, to an elevation of above 400 feet. To the southwest of the Central Plain is the more mountainous part of the island, the distinctly volcanic portion, where the hills rise to an elevation in some cases of more than 1000 feet. The highest of these hills is Boggy Peak, with an elevation stated as 1360 feet, and several others, as Bottle Peak and McNish Mountain, reach 1000 feet. These hills are of volcanic materials and show, as Spencer points out, the erosion features of a mountain plateau region, with narrow ridges separating the valleys. No distinct volcanic cone exists in this part of the island, but several hollows in the hills have been described as volcanic craters. It is doubtful if any crater is still in a recognizable state in the island. The hills around Five Islands Harbor are of the same volcanic materials as those in the southwest of the island, but here again there is no definite crater, unless indeed the basin of the harbor represent such a one. Southwest of the Central Plain the ground is too hilly to allow of large continuous cultivations such as are found in the Central Plain and in the limestone country to the northeast, and in this volcanic portion extensive cultivation has been largely abandoned, although the woods have been mostly cut off for fire wood.

The rest of the island is and has been under cultivation for a long period mostly in sugar cane, and, like all of these sugar-producing islands, the land is held by large estates. The only considerable town is the capital, St. John's, where there is a hotel. Access to outlying localities must be had mainly by driving. In this way I visited points along the coast and certain places in the interior. Such localities as could be reached by walking from St. John's were also visited. As the island is not large, the three weeks spent at St. John's enabled me to visit most of the localities where fossils were likely to be met with. I was also able to examine collections of the rocks of the island at the office of Mr. Tempany, and Mr. Forrest presented me with specimens of the landshells and some fossils. To compare with the marine shells found in the soil of the Central Plain, collections were made of the marine fauna along the shores

of St. John's Harbor and north to Corbizon Point. The land shells now living in the island were collected (when encountered) for comparison with the faunas of neighboring islands, but this collection is probably not complete. Upon the field notes and observations on the geology the following description of the geology of Antigua is based.

The first notice of the geology of the island of Antigua appeared in 1819 as a preliminary paper in the *American Journal of Science*,¹ by Dr. Nicholas Nugent, of Antigua, but this was followed two years later by a fuller paper by Dr. Nugent, entitled, "A Sketch of the Geology of the Island of Antigua,"² published in the *Transactions of the Geological Society of London*.

Dr. Nugent's paper was communicated to the Geological Society on November 5, 1819, and was accompanied by a collection of rocks and fossils to illustrate the paper; of which collection the fossil corals have been studied about forty years after their presentation by P. Martin Duncan. The mollusks have never been worked over and a list of the species published. Later, in 1839, Professor S. Hovey, of Yale and Amherst Colleges, visited the island, and with Dr. Nugent as guide, examined some of the principal localities. Upon his return to America he published a paper³ on the "Geology of Antigua," compiled, as he himself states in this communication, from Nugent's "Sketch" and from a paper by Dr. Thomas Nicholson, written for the *Antigua Almanac and Register*. Dr. Nugent divides the geological formations of the island into four, of which the basal member, No. 1, is described as "trap and trap-breccia," No. 2 is "stratified conglomerate," No. 3 is "chert," and No. 4 is "marl or calcareous rock." In his maps he reverses the order of the "stratified conglomerate" and the "chert," but explains in the *Appendix*⁴ that this was a mistake, although he at one time entertained this view of the structure of the island. Dr. Nugent's paper, which shows keen observation, remained for long the classic on Antiguan geology, until the appearance of M. J. C. Purves's Geological Sketch of the

¹ *Am. Jour. Sci.*, ser. 1, Vol. I (1819), p. 140. Wm. Maclure refers to the island of Antigua in his "Observations on the Geology of the West Indian Islands, from Barbadoes to Santa Cruz," but he did not visit the island. See *Journal Acad. Nat. Sci. Philadelphia*, Vol. 1, pt. 1, 1817.

² *Trans. Geol. Soc.* ser. 1, Vol. V (1821), pp. 459-475.

³ "Geology of Antigua," by Prof. S. Hovey, *Amer. Jour. Sci.*, ser. 1, Vol. XXXV (1839), pp. 75-85.

⁴ Extracts from a letter to Professor William Buckland, one of the Vice-presidents of the Geological Society of London, from Dr. Nugent. *Trans. Geol. Soc.*, series 1, Vol. V (1821), p. 470.

island of Antigua, which was published in 1885, in the *Bulletin du Musé Royal d'Histoire Naturelle de Belgique*.⁵ This paper by M. Purves is much fuller than that by Nugent, and he distinguishes more divisions in the geological formations. The divisions of M. Purves are as follows:

- H. Horizontal marls.
- G. Upper limestones and marls.
- F. Upper tuffs.
- E. Lacustrine or fresh-water chert.
- D. Volcanic sands and sandstones.
- C. Lower limestone or marine chert
- B. Lower stratified tuffs.
- A. Porphyrites and volcanic agglomerates.

Of these "A. Porphyrites and volcanic agglomerates" is the No. 1 of Nugent, "trap and trap-breccia"; "B. Lower stratified tuffs" is the "stratified conglomerate" No. 2 of Nugent; C, D, E, and F, of Purves come in the "chert" of Nugent No. 3, who did not recognize any distinction between the marine and the fresh-water cherts; while divisions G and H of Purves are included in the "marl or calcareous beds," No. 4 of Nugent. Indeed, it is rather doubtful if Nugent recognized the horizontal marls at all. This paper of M. Purves is accompanied by a geological map of Antigua, upon which the divisions which he recognizes are set down, and a geological section from St. Mary's Rectory to Drew's Hill and thence to Hodge Bay is given to show the structure. This map indicates a fault, with upthrow to the northeast and general N. W.-S. E. strike, dislocating the formations so that D, "the volcanic sands," is brought to the surface and lies next to F, the "upper tuffs." This makes the lacustrine or fresh-water cherts appear at the surface in two bands traversing the island from northwest to southeast. Several minor faults are shown on this map, and I observed a number which have not been mapped. This fault, as indicated by Purves, runs from about $\frac{1}{2}$ mile south of Corbizon Point on the northwest coast to the small bay between Isaac Point and Standfast Point which lies to the southwest of Willoughby Bay at the southeast of the island. It is of interest in connection with the paper by Guppy mentioned below. Each of the eight divisions of the formations of the island enumerated by Purves is described in detail as regards its composition and character, but little information is given in regard to the

⁵ "Esquisse géologique de l'île d'Antigua." *Bull. Mus. Roy. Hist. Nat. Belg.*, Vol. III, 1884-85, pp. 273-318.

organic remains, and that of a very general kind, only the genus being noted in many cases. A short list of corals from the lower marine chert and limestone, C, is given, however, which will be referred to later in this paper.

Some reference to the movements of elevation and subsidence of Antigua is given in a paper by Dr. J. W. Gregory, "On the Palæontology and Physical Geology of the West Indies,"⁶ and a few additions to the palæontology of Antigua are there noted.

The next paper to be published dealing with the geology of Antigua is by Professor J. W. W. Spencer, "On the Geological and Physical Development of Antigua"⁷ which appeared in 1901. This gives a revision of the formations of the island, as follows, the basal member being placed at the bottom:

8. Recent deposits, raised beaches.
7. Cassada Garden gravels.
6. Friars Hill series, pebbles and marl.
5. Hodge's Hill calcareous sandstones.
4. White limestone or Antigua formation.
3. Tuffs and included marls and chert.
2. Seaforth limestone.
1. Igneous basement.

Comparing this with the divisions as recognized by Purves, given above, the first division, 1, corresponds to his A; that is, the "igneous basement" of Spencer is the "porphyrites and volcanic agglomerates" of Purves. Spencer's Seaforth limestone does not seem to have been recognized by Purves, although it doubtless exists near Seaforth; and I was shown specimens from this horizon by several collectors, said to have come from the base of the stratified tuffs. Spencer's No. 3, "Tuffs and included marls and chert," includes divisions B, C, D, E, and F of Purves, these formations occupying the "Central Plain" of Antigua. Purves's division G, upper limestones and marls, is the same as Spencer's No. 4, "White limestone or Antigua formation," and may also include his division 5, Hodge's Hill calcareous sandstone. Spencer's divisions 6 and 7, "Friars Hill series" and "Cassada Garden gravels," were not recognized by Purves; while his division 8 is the same as the "horizontal marl" of Purves. Upon the whole, this division of the formations recognized by Spencer agrees with the observations which I was able to make while on the island better than do those of Purves or Nugent, although in each

⁶ *Quart. Jour. Geol. Soc. London*, LI, 1895, p. 295.

⁷ *Quart. Jour. Geol. Soc. London*, LVII (1901), pp. 490-505.

case the formation described may be readily recognized. Spencer's divisions seem to be more in accordance with the history of the development of the island as indicated in the record preserved in the rocks.

Spencer's paper is accompanied by a geological map of Antigua upon which he has laid down his divisions 1, 3, and 4; the other divisions which he recognizes being probably too local and too ill-defined in outline to be mapped. No faults are shown and no geological section accompanies the map.

The latest paper upon the geology of Antigua which has appeared is by R. J. Lechmere Guppy,⁸ following an examination of the island made in 1910. As Mr. Guppy states, this examination, on account of his physical disabilities, was necessarily incomplete. His visit to the island was to see if any trace of the "Great Antillean Dislocation," postulated in his paper, "Geological Connections of the Caribbean Region"⁹ as extending from Trinidad to Sombrero and thence through the northern part of the island of Haiti, was to be found in Antigua. This great fault, Mr. Guppy thinks, passes through Antigua, through the Central Plain, from Willoughby Bay to St. John's Harbor; the occurrence of which two bays is his principal argument in favor of this fault. Purves, on his map of Antigua, indicates a fault in somewhat the same position as this Great Dislocation of Guppy, but the fault as shown by Purves does not take the same course, running from a little south of Corbizon Point on the northwest coast, about 2 miles to the north of the fault indicated by Guppy (which starts at St. John's Harbor), to a bay between Isaac Point and Steadfast Point, about a mile to the west of the head of Willoughby Bay. Moreover, the fault shown by Purves is not indicated as a dislocation of great magnitude, while that of Guppy is a "Great Dislocation," bringing up the "older beds" of the Antigua Formation of Spencer, which, according to Mr. Guppy, "is of a very Cretaceous aspect." Upon what he bases this statement is not explained, the evidence of the fossils contained in this Antigua formation points to its being of Oligocene age, as will be shown later. But Mr. Guppy, it seems, is not a believer in the occurrence of the Oligocene in the West Indies, as he remarks in this paper (p. 684): "Even so eminent a professor as J. W. Gregory has fallen into the common error of mixing up the Miocene with the Eocene, and calling the result 'Oligocene.'" Guppy's paper does not add much data for fixing the

⁸ R. J. L. Guppy, "On the Geology of Antigua and other West Indian Islands with reference to the Physical History of the Caribbean Region," *Quart. Jour. Geol. Soc. London* (1911), Vol. LXVII, pp. 681-700.

⁹ Guppy, *Trans. Canad. Inst.*, Vol. VIII, 1908-1909, p. 373.

age of the white limestone or Antigua formation, although he records having visited "a marl pit about 2 miles from St. John's" with Mr. W. R. Forrest (doubtless the one on Marble Hill, which I visited twice, once in company with Mr. Forrest) in which he found casts of *Pholadomya* and also of *Turritella*. Upon my visit to this locality in company with Mr. Forrest, we were not so fortunate, finding only the small, badly preserved branching corals, common in the marl everywhere, but Mr. Forrest remarked to me that *Turritellas* were sometimes found here as casts, and also casts of bivalves. The preservation of the fossils in these soft marls is very imperfect, and secondary crystallization obscures the structure. They are rarely determinable specifically. The major part of Mr. Guppy's paper is taken up in discussing the "Great Dislocation," of which, during my stay upon the island, I did not see any evidence; nor has its presence been detected by Mr. R. W. Forrest, who has given much attention to the geology of the island.

The general succession of the formations in Antigua has been discussed by Nugent, Purves, and Spencer, and a brief review of their several arrangements of the strata has been given above and their correlations indicated. From my own observations, a slightly different arrangement has been deduced, as follows:

TABLE OF THE GEOLOGICAL FORMATION OF ANTIGUA.

Recent and Pleistocene	9 Salt pond and mangrove swamp deposits, in process of formation. 8 Raised beaches, horizontal marls of Purves. 7 Shell beds of the Central Plain, probably including the Cassada Garden gravels of Spencer. 6 Friar's Hill gravels and marls of Spencer.
Pliocene	Break.
Miocene	Break.
Oligocene	5 Hodge's Hill calcareous sandstone. 4 Antigua formation of Spencer, white marls and white limestone. 3 Water-deposited tuffs and shales, with included marls and cherts. 2 Seaforth limestone (perhaps Eocene).
Eocene (?)	1 Igneous basement, mainly of volcanic materials, but intersected by dykes as late as the white limestone of the Oligocene.

The water-deposited beds of the island are apparently all included in the Oligocene and Pleistocene; the Miocene and Pliocene are entirely wanting, indicating that the island was not submerged during this time. But a submergence occurred at the end of the Pliocene which permitted the formation of marine deposits in many parts of the island. The movement of the island at present appears to be upward, and the formation of salt pond and mangrove swamp deposits at many places along the coast line is still in progress. The age of the accumulation of the "igneous basement" is set down in the above table as possibly Eocene, not from any fossils which it contains, but because the bedded deposits of the Oligocene appear to overlie it. The volcanic activity continued, however, into the Oligocene during the time of the deposit of the tuffs, and the white limestone itself is intersected by dykes of the igneous material. These deposits will now be described in more detail.

1. THE IGNEOUS BASEMENT.

This is what Dr. Nugent has called the "trap formation"; it is M. Purves's "porphyrites and volcanic agglomerates," or the "foundation rocks of the island" or "igneous basement" of Spenceer. I have used Spencer's term. The rocks included in this formation lie to the west of a line drawn from the head of Five Islands Bay, southeasterly towards English Harbor, and they lie in the southwest part of the island. They are exposed along the coast from the mouth of Five Islands Bay to the southwest corner of the island and thence east to the head of Falmouth Harbor. I inspected this region in company with Mr. Forrest from St. John's to St. Mary's, Old Road (nearly due south of St. John's), and thence along the south coast to St. Mary's Rectory at the southwest extremity, and from there up the west coast to St. Mary's in the Valley, and back to St. John's by the Central Plain. Mr. Tempany showed me his collection of these rocks, which corresponded with those seen on the trip with Mr. Forrest. They consist of massive igneous flows and subaerially deposited ashes, mainly in layers, and with many volcanic agglomerates, consisting of ash and volcanic fragments held together by the material of the flows. Large volcanic bombs occur in this agglomerate with fragments down to fine lapilli and ash. The flows are mainly pyroxene andesite, often compact; and also basalt, or the same material as the pyroxene andesite with much olivine. Dykes of compact andesite and basalt intersect the tuffs and agglomerates. The rocks are prevailingly andesitic, and the tuff and

agglomerate is in excess of the material in the form of flows. Many of the tuffs and other materials have undergone alteration, and, according to the statements of Mr. Tempany, metamorphosed sediments occur. Such is the Seaforth limestone as described by Spencer, but specimens of this rock which I was shown in collections do not show metamorphism to any considerable extent. Water-deposited tuff may occur, at least near the borders of this formation, and in the tuffs of the Central Plain area I saw deposits not greatly different from those observed in these igneous foundation rocks of the island. No definite volcanic cone from which these deposits came is now in existence, all the hills being much eroded and dissected. Remnants of such cones may exist near Five Islands Bay, or the bay itself may represent the site of a crater. Another remnant of a crater was reported as being in existence near the southwest corner of the island, but no cone exists there at present.

2. THE SEAFORTH LIMESTONE.

I did not visit the type locality of this material, and only had the opportunity of inspecting two lots of specimens from the formation. Spencer describes it as "occurring at a few points in the valleys of the mountain zone" or among the rocks of the igneous basement; and states that it is a compact dark gray limestone. Mr. Tempany gave a similar description of its appearance and occurrence, but the specimen of it which he showed me in his collection was a somewhat flinty rock with undoubted *Orbitoides* in it. Mr. Gillie, rector of the parish of St. Mary's, who resides near the southwest corner of the island, showed me some pieces of a limestone from Seaforth of quite a different character. It was a dark gray compact limestone, but crowded with the shells of bivalves, probably oysters, that were specifically undeterminable. There was nothing in either of these specimens to lead me to suppose that they were older than Oligocene, while the occurrence of the *Orbitoides*, in a form not greatly different from that found in the white limestone, rather pointed to this age for the deposit. Purves did not recognize this Seaforth limestone.

3. WATER-DEPOSITED TUFFS AND SHALES, WITH INCLUDED MARLS AND CHERTS.

These formations occupy almost the entire area of the Central Plain. They include the divisions recognized by Purves under the names B, Lower stratified tuffs; C, Lower limestone and marine chert; D, Volcanic sands and sandstones; E, Lacustrine and fresh-

water chert; F, Upper tuffs. They have been placed together by Spencer as one group of deposits, and while it may be possible locally to recognize the divisions made by Purves, the cherty limestones of marine origin, and possibly also those of fresh-water origin, are in more or less lenticular deposits and not continuous. The division D of Purves, "Volcanic sands and sandstones," is locally developed and underlies in some places the fresh-water cherts or the layer containing the fossil wood, but it does not differ very much in appearance from some phases of B, the lower stratified tuffs. This division B of Purves, the lowest member of this group of deposits, is found to the west of the Central Plain, and well developed along the southern shore of St. John's Harbor. The beds have the appearance of a buff-colored sandstone, but on close examination the fragments of which it is composed are seen to be angular, not water worn, and to consist of volcanic rock and feldspar. These lower beds may have a higher dip than those of the Central Plain— 20° – 30° , as against 12° – 15° —and the dip is more to the north in many cases. But as the higher rocks in this lower series of tuffs are encountered, the dip diminishes and becomes more northeast. At the level of the lower limestone and marine chert as seen just to the south of St. John's (about a mile south of the town) the tuff becomes almost white from admixed kaolin, and has this lower dip of 12° N. E. It is in some places soft, in others hard and compact, and almost pure white except for black specks of magnetite. This magnetite forms black layers on many of the recent sea-beaches and consists of octahedral crystals and angular fragments of crystals. The limestone deposit, which in places is altered to a flint or chert, contains corals, those from the Nugent collection in the possession of the Geological Society of London have yielded the following species (Duncan):¹⁰

Astræa cellulosa var. *curvata* Duncan.

Astræa megalaxona Duncan.

Astræa antillarum Duncan.

Solenastræa turonensis Mich.

Isastræa conferta Duncan.

Isastræa turbinata Duncan.

Stephanocænia tenuis Duncan, also found in the lower tuffs.

Cæloria dens-elephantis Duncan.

Astroria polygonalis Duncan.

Astroria affinis Duncan.

Astroria antiquensis Duncan.

Astrocænia ornata Ed. and H.

Aheopora dædala Blainv., also vars. *regularis* and *minor*.

Stylocænia lobato-rotundata (Mich.).

¹⁰ *Quart. Jour. Geol. Soc. London*, Vol. XIX, 1863, p. 477.

These cherts and cherty limestones occur also at Jackass Point in St. John's Harbor. The same character of rock, marly limestone with associated flint and chert, and with corals, etc., is found in the town of St. John's, and is, in fact, the material upon which the cathedral is built. At the cathedral it is mostly chert, and the flint and chert are found to the southeast of the town along the roads. Mollusks have been reported from this chert, but no species have been determined, although doubtless a considerable fauna will be found in the Nugent collection when it comes to be studied. This last line of this rock, which runs southeast from St. John's Cathedral, is probably another layer of the marl and chert parallel to the one mentioned as running from Jackass Point southeast to near the sugar factory, one mile south of St. John's.

It is seen exposed, and fragments of the flint are plentiful along the roads to the southeast of the town, south of the Botanic Station; indeed, it forms some of the small hills in this section. These deposits seem to be more or less discontinuous and are only to be seen where the ground becomes too hilly or the soil too stony for cane cultivation.

The "volcanic sands and sandstones," bed D, of Purves are even more discontinuous. They are characteristically developed, as he describes them, along the northwest sea-coast at Dry Hill and at Corbizon Point, where they are overlaid by the "lacustrine chert" of Purves. Traces of these "volcanic sands" are seen in some places to the east of St. John's, but their horizon is only marked in some places by sandy lumps and concretions in the white tuffaceous rock. Sands at the horizon for these "D" beds are seen in patches from Corbizon Point to the southeast, into the interior of the island; but that they are often wanting, as may be seen on the hills east of the Botanic Station, where a continuous section of the white tuffs, some with sandy modules or concretions representing the horizon of "D," the "volcanic sands," is overlain by the "lacustrine chert" with fresh-water shells imbedded in its mass. At the Public Cemetery, also, the sands are wanting, only the sandy nodules mark the horizon of these beds. The white tuffs above the "marine chert" are sometimes partly replaced by the lenticular masses of the volcanic sands, or sometimes these sands are entirely wanting. These white tuffs owe their color to kaolin from the alteration of feldspar in the volcanic ash, and are mixtures of ash (usually fragments of feldspar) and kaolin. The admixture of kaolin becomes so plentiful in the upper beds that the rock might be called either a water-deposited

tuff or a shale; in fact, it is of much the composition of pipe-clay. This is particularly true of the layers above the lacustrine chert horizon, where these virtual shales become very white and thin-bedded and are hard to distinguish, when massive, from the overlying marls. These are the upper tuffs of Purves, and are quarried at Scotts Hill.

When the "volcanic sands and sandstones" are typically developed, as at Dry Hill or at Corbizon Point, they form the base of the section. They are dark reddish or purplish in color, with numerous concretions, resembling boulders, of a somewhat harder character, and are made up of volcanic sand and gravel, all water worn, with small pebbles of the compact hard andesite of the igneous basement, from which they are doubtless derived. They are but slightly compacted; firm, but yielding readily to the pick, and crumbling easily in the fingers when in detached fragments. They are overlaid by a few feet of yellowish tuff conglomerate, consisting of rolled fragments of a lighter color, with much green earth in minute particles, which gradually passes into the impure yellowish marls with the flint layers of the "lacustrine or fresh-water chert." The exposure of these flinty layers at Dry Hill follows the strike of the rock for some distance, and these beds at this point have furnished the following section:

Section at Dry Hill.

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|--|----------|
| 5. Compact shale with plant impressions | 10 ft. |
| 4. Hard impure limestone with two, or sometimes three,
layers of flint, carrying fresh-water shells; the flint layers
varying from one inch to four inches thick, and the fossils
occupying about one inch thickness in each case | 2 ft. |
| 3. Hard impure limestone without fossil layers | 2 ft. |
| 2. Yellowish tuff conglomerate, pebbles of tuff and andesite | 5 ft. |
| 1. Dark reddish or purplish volcanic sandstone | 18 ft. + |

The base of the volcanic sands is not exposed at this locality nor at Corbizon Point. Several small faults exist near the north end of the Dry Hill exposure, one dislocates the measures about 25 ft. with an upthrow to the north, and one or more must exist between Dry Hill and Corbizon Point, the total upthrow to the north aggregating upwards of 400 feet, as the same succession of beds is to be noted at Corbizon Point as is given in the above section at Dry Hill. No exposures of the rock in place can be seen along the coast between Dry Hill and Corbizon Point, the beach being flat and sandy; and

inland there is a salt pond, while still further inland the cane cultivation covers all exposures. At Corbizon Point, however, the upper flinty layers carry fragments of silicified wood, and this is the horizon of the silicified wood for which Antigua is noted. This horizon may be traced across the island by the silicified wood and to some distance to the southeast by the flint and chert with the fresh-water fossils. Mr. W. R. Forrest informs me that the silicified wood is in place along the north shore of Willoughby Bay; but, if so, it is not this layer, always supposing that the map of Purves is correct. The fresh-water fossils have not been determined specifically, a list of the genera found is given by Purves. Collections of them which I obtained at Dry Hill are now being studied and will be reported upon later.

The silicified wood, for which the island is noted, probably all comes from this horizon. It is found throughout the Central Plain, especially in the central part of the island, and lies about on the surface in fragments of varying sizes, although nowhere, at present, are trunks of 14 feet long by one foot or more in diameter encountered, such as are described by Dr. Nugent. These silicified woods are found scattered about upon the surface, but are rarely seen *in situ*; they are very plentiful at Bellevue and at Cassada Garden. They include both Monocotyledons and Dicotyledons, but have never been studied specifically. Purves mentions having found stems and fruit of *Chara* in the beds carrying these deposits. The shales at Dry Hill which overlie the fresh-water, mollusk-bearing flinty layers carry fragments of leaves of palms and other vegetable matter; these beds are mixtures of kaolin and volcanic ash, and, while brownish or dun-colored from the admixed vegetable matter, they are evidently a part of the white shales and tuffs of the upper layers of this division. As has been stated, these upper shales and tuffs are well exposed at Scotts Hill, some two miles to the southeast of St. John's, where they are quarried for road metal. They are here hard and compact, breaking into angular fragments on exposure, and wearing down, when used on the roads, to a tenacious clay. This rock consists, as seen under the microscope, of kaolin mixed with volcanic ash, the kaolin largely predominating. It is partly cemented by secondary silica from the feldspar of the volcanic ash. It becomes calcareous towards the top and passes upward into the marls of the white limestone or Antigua formation. Indeed, when it is hard and compact, this rock closely resembles the harder parts of the marl, and the application of an acid is often necessary to distinguish it from the true marl.

The total thickness of this division is upwards of 2000 feet or more, and of this more than half is below the lacustrine flint layer; the bottom of the formation is hard to define, as it is not easily distinguished from the bedded deposits of the basal igneous complex. But of the distinctly bedded deposits, which are exposed in many places and always with the same general north or northeast dip, the thickness must be at least 2000 feet. The division is composed of the volcanic material of the igneous basement, reworked by water, and water deposited; mixed likely with other volcanic material which, erupted during the deposition of these beds, fell into the water; and was distributed on the sea bottom.

As indicated above, these tuff beds, with their included marls and cherts, appear to pass upward into the marls and limestones of the Antigua formation without any stratigraphic break, or the Antigua formation rests conformably upon them. At several places along the contact of the marls with the tuffs and shales shallow wells have been sunk for water, and while the contact of these two formations is seldom exposed, the conformable character of it is indicated by these diggings. When the Antigua formation itself is found well exposed near the contact, the dip of the marls is about the same as that of the tuffs, and is in the same direction; that is, the marls are found to dip gently at 10°-12° to the northeast in the same way as the tuffs. There is certainly no indication of a fault separating the two formations as suggested by Mr. Guppy. The fossils of the included marls and cherts, interbedded with the tuffs and shales, do not indicate any other age than Oligocene, which is the age of the Antigua limestone as indicated by its fossils. But the species that have been observed in the Antigua limestone are only in part the same as have been determined from the tuffs and included marls and cherts. These tuffs were, in part at least, shallow water formations; mud cracks and even ripple marks were observed by me in the tuffs underlying the lacustrine cherts, and the presence of these fresh-water deposits (the lacustrine cherts) indicates land at this time. The tuffs may have accumulated rapidly when they are coarse in grain, as these volcanic conglomerates which underlie the fresh-water deposits, but the finer material of the thin-bedded tuffs which overlie this horizon were probably slowly deposited and in water of greater depth. This was likely the case with the marls of the Antigua formation also, in great part; although some of the harder limestone beds of this deposit have the appearance of coral-reef material.

4. THE ANTIGUA FORMATION OF SPENCER.

East of a line running from near Wetherill's Point to the head of Willoughby Bay the surface of the island is composed of the Antigua Formation (as Spencer has named it), a white chalky or marly rock with harder layers which may be properly called limestone. In the cane cultivations with which the island is covered from the Central Plain easterly, this formation may often be recognized by a pronounced blackness of the soil where the marls are encountered. They are often exposed in road-cuttings, or on the hillsides by artificial diggings ("marl pits") for material to be used as road metal; and where soft, the dip is obscure, but where more hard the same northeasterly dip is seen that was so characteristic of the tuffs and shales. As soon as the harder limestone layers are encountered, they make hills with a gentle easterly slope, but a steeper westerly one on the escarpment side of the hill; and this harder part of the marl or the harder limestone is often exposed upon this escarpment side of the hill in considerable cliffs. Where the harder limestones outcrop along the coast as at Wetherill Bay and Hodge's Bay along the north coast, and at High Point and other places to windward along the east coast, around to Willoughby Bay on the southeast coast, these harder layers form sea cliffs. These harder layers, too, form in many cases the capping of the hills, which are ridges with an even summit in such cases. Where the dip can be seen, on such harder layers, it is uniformly to the northeast, and the thickness of this Antigua formation, as indicated by this dip, must be upwards of 1500 feet at least. The harder layers have generally the same organic remains, and this seems to indicate (unless the formation is faulted) that there are several parallel hard layers. The fossils contained in the softer marls are usually corals, in a much altered and crystallized condition; the crystallization being due to the deposit of carbonates (as calcite and dolomite) or to silica in the form of quartz, crystals of which substance are frequently seen in the marls. The harder layers are often compact limestone, sometimes nearly barren of fossils, at other times crowded with organic remains. The most characteristic fossil in the harder layers is an *Orbitoides*, which has been determined by T. Rupert Jones (and this determination later confirmed by Dr. Lang, of the British Museum) as *Orbitoides mantelli* Mort. This *Orbitoides*, in many cases, forms the bulk of the limestone, and water-worn pebbles from the seashore frequently show only sections of this *Orbitoides* with no other fossil. But in other layers are found shells of oysters, peccens, and other pelecypods, while in

other cases the rock is composed of masses and fragments of corals. The corals of the Nugent collection were determined by Duncan,¹¹ who gives the following list of species:

Duncan's List of Corals in the Nugent Collection from the Antigua Formation.

Astraa crassolamclata Duncan, with the varieties *magnetica*, *pulchella*, *nobilis*, *minor*, *nugenti*, *magnifica*.

Astraa antiguensis Duncan.

Astraa endothecata Duncan.

Astraa tenuis Duncan.

Astraa barbadensis Duncan.

Astraa radiata Lam., var. *intermedia* Duncan.

Astraa costata Duncan.

Rhodaraa irregularis Duncan.

Alveopora dadala Blainv., var. *regularis* Duncan.

Alveopora microscopica Duncan.

Alveopora fenestrata Dana.

Of these the species *Alveopora dadala* Blainv. is common to the tuffs and to the Antigua Formation. The corals collected by Professor Spencer were referred to Dr. T. Wayland Vaughan for determination, who reported the following list:

Trochosmia n. sp.

Stylophora sp.

Stephanocania sp.

†*Astrocania ornata* Ed. and H.

Brachyphyllia sp.

**Orbicella (Astraa) crassolamellata* (Duncan).

†*Orbicella cellulosa* (Duncan).

**Orbicella endothecata* (Duncan).

Orbicella sp.

Symphyllia n. sp.

†*Astroria polygonalis* Duncan.

Oroscria n. sp.

†**Alveopora regularis* Duncan.

Porites n. sp.

Of these species, the ones marked with an asterisk (*) are in Duncan's list from the white Antigua limestone, and the ones marked with a dagger (†) are found in Duncan's list of the corals in the Nugent collection from the tuffs. Dr. Vaughan recognizes eight species not in Duncan's list. One species is common to the tuffs and the white limestone (†*). As Spencer remarks, this

¹¹ *Quart. Jour. Geol. Soc. London*, Vol. XIX, 1863, p. 410.

finding of the same species in both the tuffs and the white limestone would point to their forming really but one geological unit, "although characterized by great changes in the physical conditions during the accumulation of the system." What has been said of the gradual passage of the upper shales and tuffs into the marls and their apparent conformability point to these formations forming one geological unit. As to the age of the corals examined by Dr. Vaughan, he notes that the coral fauna of the Antigua formation "is identical with that of the lower beds of the upper Oligocene formation of southwestern Georgia."

The mollusks collected by Speneer were referred to Dr. Dall, who afterwards determined one of the forms as *Pecten (Chlamys) anguilensis* Guppy, and described one as *Pecten (Plagiocentrum) gabbi* Dall, referred to below in the list of species in the collection made by me in Antigua.

Professor Gregory,¹² lists two species of echinoids sent to him by Mr. Forrest, and these are also among the species collected by me in Antigua. They are, as given by Gregory, *Echinanthus concavus* (Cott.) and *Echinanthus antillarum* (Cott.). With the exceptions of the two *Pectens* noted above, as determined by Dr. Dall, no mollusks appear to have been recorded from this Antigua white limestone, so that the few which I was able to secure will help to fix the age of the formation. The limestones in some places carry many species of *Pectens*, and as these are frequently determinable even in fragments, more attention was given to collecting them than to corals, foramenifera, etc. Although difficult to extract from the rock, I was fortunate enough to obtain five known species or varieties of Oligocene *Pectens* as well as two new species of this genus, and a new species of oyster, a *Turritella*, and six or seven species of echinoids. These, with the corals that have been determined as Oligocene, will serve to confirm the age of the formation. The list of species collected from this Antigua formation is given below.

Species collected from the Antigua Formation.

Diplotheccanthus concavus (Cott.).

Clypeaster concavus Cott., 1875.—Cotteau, Kongl. Sv. Vet. Akad. Handlingar, B. 13, No. 6, p. 16, pl. II, figs. 4-8.

Echinanthus concavus (Cott.).—Gregory, Quart. Jour. Geol. Soc. London, Vol. LI (1895), p. 295.

This is the commonest echinoid in the Antigua white limestone,

¹² Gregory, Quart. Jour. Geol. Soc. London, Vol. LI, 1895, p. 295.

and was found in great numbers at Hodge's Bay and along the shores at Willoughby Bay, and also commonly at High Point.

Diplothecauthus antillarum (Cott.).

Clypeaster antillarum Cott., 1875.—Cotteau, *loc. cit.*, p. 15, pl. II, figs. 1-3.

Echinanthus antillarum (Cott.).—Gregory, *loc. cit.*, p. 295.

Not *Echinanthus antillarum* Cott., 1875.—Cotteau, *loc. cit.*, p. 26, pl. IV, figs. 9-12.

Less common than *D. concavus* (Cott.), this large species was found at Willoughby Bay only.

Sismondia antillarum Cott.

Sismondia antillarum Cott., 1875.—Cotteau, *loc. cit.*, p. 17, pl. III, figs. 1-4.

A small species found only at Willoughby Bay.

Schizaster clevei Cott.

Schizaster clevei Cott., 1875.—Cotteau, *loc. cit.*, p. 29, pl. V, figs. 7, 8.

A rather small specimen which probably belongs to this species was collected at Willoughby Bay. It may prove to be new.

Echinolampas anguillæ Cott.

Echinolampas anguillæ Cott., 1875.—Cotteau, *loc. cit.*, p. 24, pl. IV, figs. 5-8.

A single example of this species was collected at Willoughby Bay.

Metalia sp. indet.

Fragments of two additional species, one probably belonging to the genus *Metalia* and the other to *Eupatagus*, were collected, some at Hodge's Point and some at Willoughby Bay. While several fragments of each species were collected, none are in sufficiently perfect condition to describe. One specimen from Hodge's Bay is a fragment of a very large species, but somewhat less than one-third of the test is represented.

Pecten (*Æquipecten*) **oxygonum** Sowb.

Pecten oxygonum Sowb.—Quart. Jour. Geol. Soc. London, VI, 1849, p. 52.

This is the species which Gabb has determined as belonging to this unfigured species of Sowerby; the specimens collected agree perfectly with those determined by Gabb as belonging to this species in his specimens from Santo Domingo (now in the A. N. S. P. collection). It was collected at Hodge's Bay.

Pecten oxygonum optimum B. and P.

Pecten oxygonum optimum B. and P.—Brown and Pilsbry, Proc. A. N. S. P., 1912, p. 511, pl. XXIII (numbered XXIV), fig. 2.

Pecten parancensis d'Orb.—Gabb., Journ. A. N. S. P., VIII, p. 347, pl. 45, fig. 24. Not of d'Orbigny, Voy. Amer. Merid. Palaont, p. 132.

This variety of *P. oxygonum*, described in "Fauna of the Gatun Formation, Isthmus of Panama, II," a year ago, is based upon a

specimen referred by Gabb to *P. paranensis* d'Orb. It was found at Willoughby Bay, several specimens being taken. Gabb's specimen came from the Reventazon River, Costa Rica, and not, as noted by Dall, from Santo Domingo.

Pecten (*Chlamys*) *anguillensis* Guppy. Plate XVIII, figs. 4, 6, 7, 8.

Pecten anguillensis Guppy.—Proc. Sci. Asso. Trinidad, 1867, p. 175, figured in Geol. Mag. Decade, II, Vol. I, 1874, pl. XVIII, fig. 24.

This species was the commonest *Pecten* in the Antigua limestone, and is recorded as having been brought from Antigua by Spencer (see Dall, "Tertiary Fauna of Florida," p. 715). It was collected by me at Wetherill's, Hodge's Bay, and Willoughby Bay. It was particularly plentiful at Wetherill's Bay, but few specimens could be detached entire from the rock surfaces. The figure given by Guppy does not show the secondary radial striation, and is thus misleading, but the species may readily be recognized by its 10-11 ribs, much fewer than in the other fossil *Pectens* of Antigua. Its living representatives, probably descendants in one case, are *P. antillarum* Recluz of Guadeloupe and other islands of the West Indies, and *P. luculentus* Reeve of North Australia.

Pecten (*Æquipecten*) *thetidis* Sowb.

Pecten thetidis Sowb.—Quart. Jour. Geol. Soc., VI, 1849, p. 52.

Pecten thetidis Sowb.—Gabb, Trans. Amer. Phil. Soc., new series, XV, p. 256.

This species was collected at Hodge's Bay, and agrees well with specimens so named by Gabb in his Santo Domingo collection in The Academy of Natural Sciences of Philadelphia. It was fairly common; did not become silicified so commonly as the last species, and commonly acquired a black color on exposure to the weather. The species is small, evenly ribbed, and seems to belong to the first of the two varieties mentioned by Gabb.

Pecten (*Plagioctenium*) *gabbi* Dall.

Pecten (Plagioctenium) gabbi Dall, Tertiary Fauna of Florida,¹² p. 717, pl. 29, fig. 3. Not *Pecten paranensis* d'Orb., as cited by Gabb.—Jour. Acad. Nat. Sci. Phila., 2d series, VIII, p. 347.

This species is represented by one entire valve and several more or less well-preserved fragments of valves from Willoughby Bay, and, while it does not agree exactly with Dall's figure, it does agree with his description of *P. gabbi* Dall. The figure is from a specimen collected by Spencer in Antigua. The specimen referred to *Pecten paranensis* d'Orb. by Gabb was from Reventazon River, Costa Rica, not from Santo Domingo, as stated by Dall. As already noted, this Costa Rica specimen is the *P. oxygonum optimum* B. and P., and does

¹²Trans. Wagner Free Inst. Sci., III, p. 715.

not at all resemble this Antigua species. But while Dall's figure of Speneer's Antigua specimen is not exactly like this species, his description agrees so well with the Willoughby Bay specimens that I do not doubt this species is *P. gabbi* Dall.

Pecten (Amusium) antiguensis n. sp. Plate XVIII, figs. 1, 2, 3, 5.

This large *Amusium* is very common in the Antigua limestone on the sea beach at Wetherill's Bay and especially at Hodge's Bay. Its description will be found under "Descriptions of New Species." While plentiful at Hodge's Bay, the specimens were so firmly attached to the rock or imbedded in it as to make it almost an impossibility to extract entire, unbroken specimens. This species and the *P. anguillensis* Guppy were especially likely to be found silicified. This silicification has sometimes obliterated the secondary sculpture, but in other cases has preserved it in most remarkably perfect condition, as in some of these specimens. If it were not for this silicification, it would be very difficult to obtain any specimens from this hard, white limestone; but this alteration, in part or wholly, to silica makes the specimens weather out in almost complete and perfect condition.

Pecten nugenti n. sp. Plate XIX, figs. 2, 5, 6.

Hodge's Bay.

Ostrea antiguensis n. sp. Plate XIX, fig. 7; plate XX, figs. 1, 5, 6.

In some of the exposures of this limestone along the seashore, notably at Hodge's Bay and at Wetherill's Bay, the hard limestone contained many isolated oyster shells. Of these, the specimens collected at Hodge's Bay I at first referred to *Ostrea gatunensis* B. and P., but upon further examination I find that they are the same as those collected at High Point and Wetherill's Bay. These are specimens of a new species to which I have given the name of *Ostrea antiguensis*. At Willoughby Bay a much larger species of oyster was observed, perhaps *O. haitensis* Sowb., but specimens could not be obtained, as they were imbedded in the hard, compact limestone.

Spondylus sp. indet.

A single young specimen of a *Spondylus* was collected at High Point. It seems to resemble *Spondylus bostrichites* Guppy, but is too young and too fragmentary to be determined with certainty. This shell was silicified also.

Turritella forresti n. sp. Plate XX, figs. 2-4, 7, 8.

Found at Willoughby Bay by Mr. W. R. Forrest. See "Descriptions of New Species."

If incoherent or soft fossiliferous beds could be found in Antigua, such as occur in Santo Domingo or on the Isthmus of Panama and in Costa Rica, the fauna obtainable from this Antigua limestone would undoubtedly be a large one. I examined the island carefully for such deposits, but none of this soft character were met with. Further research may disclose such deposits, but unfortunately the tuffs in which they might be found have undergone much compression and they are too much altered, where they have, thus far, been found to carry fossils, to give much hope of finding them fossiliferous and at the same time soft. The limestone is sometimes in the form of a soft marl, but even this has usually undergone alteration and the fossils have been subjected to crystallization which has obliterated many characters. In some cases the organic remains have been dissolved and replaced by silica, or the shells have been dissolved away leaving a cast of the cavity, but no mould to show the exterior of the organism. The most favorable place for collecting specimens to represent the fauna that was seen was the region of Willoughby Bay, and from what I saw there it is evident that the fauna is a very large one.

That the igneous activity continued during the Oligocene, after the deposit of these limestones, is indicated by the occurrence at Crosbies of a dyke of dark andesite which has been injected into the white marl and has altered it in places, the dyke itself being also altered. This dyke is 15 feet wide or more, and is compact and not porous. This locality at Crosbies is near the northern shore and about a mile to the southwest of Hodge's Bay. Purves mentions this locality, but places it on the seashore. Angular lapilli of volcanic ash were found in the limestone at Hodge's Bay, indicating volcanic action at this time.

5. HODGE'S HILL CALCAREOUS SANDSTONE (OF SPENCER).

Professor Spencer has given this name to a calcite sandstone composed of water-worn grains of coral, shell, and other calcareous matter, found at Hodge's Hill in the northeastern corner of the island. These beds are seen along the shore at Hodge's Bay overlying the hard Antigua limestone, and resting upon them with a very flat dip. Spencer regards this contact as unconformable, but there seems to be no erosion unconformity, and the difference in dip is very slight. The material has a very different appearance (as regards compactness, for example) from the harder Antigua limestone which it overlies, but I have no doubt that it is really a part of the

same formation. It contained the *Orbitoides* and many fragments of echinoids, and furnished a recognizable *Scala*, referred to below. Spencer¹⁴ remarks of these sandstones that "one suspects the Hodge's Hill sandstones belong to an epoch not long subsequent to that of the former rocks" (Antigua limestones); a conclusion in which I certainly concur. In fact, it seems more than probable that they are only the continuation upward of this same Antigua formation.

6. FRIAR'S HILL GRAVELS AND MARLS (OF SPENCER).

An undoubted unconformity, representing a break in the deposition of the formations lasting through the Miocene and Pliocene, separates these gravels and marls from the Oligocene of the Antigua formation. These deposits of Friar's Hill rest upon the eroded surfaces of the Antigua limestone, and consist, at the base, of water-worn pebbles, derived from the underlying formations; and this layer of pebbles is overlaid by a compact, buff-colored marl stated by Spencer to have a thickness of about 12 feet, and doubtless likewise derived in large part from the underlying marl itself. The material seems to be always not greatly different from the underlying marls of the Oligocene, as though derived in each case from rock in the immediate vicinity. Spencer, also, notes that the material does not seem to have been transported to any distance. I am inclined to think it should be connected with the Cassada Garden gravels as the *shore deposit* that was formed during this depression of the island when the shell beds of the Central Plain were being laid down, and the Cassada Garden gravels are the *current-transported* materials of the same general age. I have not seen these Cassada Garden gravels overlying the Friar's Hill deposits, and at Cassada Garden the gravels rest upon the tuffs under the Antigua formation. No fossils, except those that are derived from the marls, are found in the Friar's Hill deposits, but, up to at least 150 feet above sea level, the shells of the next division cover the ground in the region of the Central Plain. The Friar's Hill gravels, according to Spencer, occur up to 200 feet above sea level, while I have traced the shell deposits of the Central Plain (as above stated) up to at least 150 feet above the sea level.

7. SHELL BEDS OF THE CENTRAL PLAIN.

Throughout the Central Plain of Antigua, from the neighborhood of St. John's to Willoughby Bay, sea shells are encountered in the soil

¹⁴ *Quart. Jour. Geol. Soc. London*, Vol. LVII, 1901, p. 499.

and lying about on the surface, being brought up in every excavation and digging up to, in the region of St. John's, 125 feet above sea level. They are found in some places upon hills to a level of 150 feet above the sea. They are not confined to the Central Plain entirely, for they were seen near St. Mary's Rectory, in the volcanic part of the island, at least 100 feet above sea level. In the vicinity of Willoughby Bay they were seen in the soil of the Central Plain at elevations of upwards of 100 feet also, but they were not noted in the soil upon the high hills near the Montpelier estate in this vicinity. The species were those now living in the sea surrounding the island. They occur in the surface soil, but it cannot be said that there is any very recognizable deposit which contains them. As they are in a superficial deposit, this is not to be wondered at; the surface soil everywhere has been disturbed for some depth on account of the cane cultivation, which covers all the available cane-producing land in the island. In some places these marine shells are found associated with recent land shells, as has been described of the raised beaches or horizontal marls of Purves, although these land shells are the species now living in the places where these marine shells occur, and have come into the soil much more recently than the marine shells. During the time of the deposition of these shell deposits the island must have stood at a level of at least 150 feet lower than at present and, in fact, have been divided into two or more islands by the sea, which occupied the Central Plain. Across this plain the sea must have been driven by the trade winds, this wind drift making a current (during the time of greatest depression) running through the Central Plain from Willoughby Bay to St. John's Harbor. The excavating power of this current may have had its part in the formation of these two bays, and of the depressions along the coast from St. John's Harbor north to Corbizon Point, such as Dickenson's Bay. The rise of tide in Antigua is slight, but it must have produced a very appreciable current in this central depression; and during the ebb and flow of the tide, until a channel was established across the inland during the time of sinking, currents due to this cause must have run in and out of the bays. Even during the time of greatest submergence such currents must have been formed and in their flow have had a tendency to scour the bottom of the bays at either end of the central depression. The currents set up by the tide or (during the time of maximum submergence) by the wind drift would be strong enough to produce the water-worn character observed in the Cassada Garden gravels. And the appearance observed in these materials of having

been transported a considerable distance would be explained by the existence of such currents. The Cassada Garden gravels, as I saw them at the type locality, occupy depressions in the general surface, where they have accumulated, and they also occur as low hills or mounds above the general surface. They may represent local channel or even shore deposits when the sea occupied this central plain. More to the east, in the bays that would be formed by such a depression, the Friar's Hill gravels and marls might have been locally formed. The general occurrence of marine shells up to 125-150 feet above sea level, wherever either in the Central Plain or in the volcanic region to the southwestern part of the island the surface soil was exposed by cultivation, is a character of the geology of the island that at once strikes the observer. And from this higher elevation down to the sea level such occurrences of sea shells are common all over the island. In the Central Plain the form of surface characterizing a raised beach has not been preserved, but nearer the sea level there are definite raised beaches, some of which were observed by Purves and named the "horizontal marls." They no doubt had an origin similar to that of the salt pond and mangrove swamp deposits that are still forming. But the marine shells of the older submergence were in large part or entirely the same species as those of these later deposits. And since the greatest depression of the island during which these shell beds of this submergence were laid down, the general movement of the island has been upward. Indeed, old maps like that accompanying Nugent's paper, compared with present conditions, would indicate that this upward movement is still going on. Evidence of the submergence is to be seen not only in the marine shells found in the soil; the underground water from the region of the Central Plain carries a large percentage of sodium chloride. In wells in this Central Plain and in the water from springs in this region the amount of sodium chloride is so high as to become characteristic of the water of the region. Thus at Gamble's Spring it amounts to 1137 parts in 100,000, as determined from an analysis made in 1906, and at Gunthorpe's well, according to an analysis made in 1905, the sodium chloride content rose to 1458 parts per 100,000.¹⁵ At Cassada Garden the sodium chloride content in the water is much less—390 parts per 100,000. Away from this Central Plain depression the amount of sodium chloride is found to decrease, and this is a characteristic of the limestone district; for instance, at

¹⁵ "The Water Supply of Antigua," by H. A. Tempany, *West Indian Bulletin*, Vol. XII, No. 4.

Parham, New Work, the salt in the water was only 14.7 parts per 100,000 in 1911. On the other hand, in the raised beach deposits in the east of the island the content of sodium chloride in the water is often as much as, or more than, that of the Cassada Garden well, and this is doubtless true of all districts recently covered by salt ponds, although they now may show no evidence of recent submergence.

The marine shells found scattered through these shell beds are apparently all recent species; they include many gastropods and a much larger number of pelecypods. A few specimens were gathered and some of the larger species simply noted. Among the gastropods the large *Strombus gigas* L. was occasionally seen, also *Melongena melongena* L., and *Livona pica* L. were often encountered. A few specimens of *Purpura* were seen and *P. deltoidea* Lam. was collected, as was also *Bullaria occidentalis* (A. Ad.) and *Modulus modulus* (L.). The pelecypods collected include *Arca chemnitzii* Phil., *Cardium muricatum* L., *Chione cancellata* L., and two varieties of *Anomalocardia flexuosa* L., but many other species were seen, especially *Codakia orbicularis* (L.) and *Codakia orbiculata* Mont. A limpet, *Fissuridea barbadensis* Gmel., was observed. Land shells, particularly *Bulimulus guadalupensis* Brug., are plentiful in the soil mixed with the marine shells, they have probably been recently introduced into this deposit from forms living in the Central Plain when it was first cleared and settled.

S. RAISED BEACHES, HORIZONTAL MARLS OF PURVES.

Along a part of the north shore of the island and also along the northeast shore down to St. George's Church there are, at certain places, definite horizontal deposits, consisting of marl with marine and land shells often mixed together, imbedded in the deposit. These have been described by Purves as the horizontal marls, and are well developed in the vicinity of St. George's Church. They are not seen at any great elevation above the present sea level, not more than 10-12 feet, and are probably old salt pond deposits. The one at St. George's Church contains plentiful remains of land shells mixed with marine species. Here I saw *Pleurodonte formosa* (Fer.) with the deeper pigment bands still showing their color; although the finer color pattern characteristic of the recent shell is lost. *Drymonus elongatus* Bolt. was also plentiful, but the specimens of *P. formosa* (Fer.) outnumbered the *Drymonus* about three to one. This Antigua species of *Pleurodonte* was only known alive, to the local collectors

from the volcanic part of the island, in St. Mary's, and is not now living, so far as known, in the north of the island. I found it living at Montpelier in the limestone district of the southeast extremity of the island in St. Philip's Parish. I collected at St. George's also the extinct *Helicina* named by Purves, *Helicina crosbyi*, which appears to be a good species, not hitherto described or figured, but his Succineas do not differ from the living *Succinea barbadensis* Guild. These two Succineas found in this marl Purves has named *S. boonii* and *S. boonii* var. *elongata*,¹⁶ and he states that they are not now living in Antigua, but they seem to me to be simply variations of the living *S. barbadensis* Guild, which is found living everywhere in the limestone district. It is to be noted that these so-called extinct forms are larger than the normal living forms; and also a large "semi-fossil" *Succinea* has been collected in Santa Cruz which belongs to the same species as these from the horizontal marls. The *Helicina crosbyi* of Purves is not known in the living state in Antigua, it seems to be really extinct. It is not the species found in the neighboring island of Barbuda, and more closely resembles one of the Jamaica species of *Helicina* than any known species, but, as stated, it is probably a good species. It is described with other undescribed species in this paper.

The list of species given by Purves of the land shells found in these marls includes *Cistula antiguensis* Shutt., now living at Wetherill's and near Montpelier, that is, at the northwest and at the southeast corners of the island, but not seen living elsewhere; and also *Subulina octona* Brug., found everywhere. The only really extinct form is the *Helicina crosbyi*. None of the marine species observed are extinct, and all are still living about the shores of the island. Such a deposit as this one at St. George's (and similar ones are known along the northeast and north shore to Boone's Point) was probably formed in much the same way as the present salt ponds. It was at one time a shallow bay, the mouth of which was cut off by the growth of mangroves, and it thus became a lagoon. Into this lagoon, the washings from the hills brought down the land shells that cover the ground, even at present. This part of the island must have been grown up in "bush" similar to the vegetation that now covers Barbuda, in which bush *Pleurodonte formosa*, *Helicina crosbyi*, *Cistula antiguensis*, *Drymus elongatus*, *Bulimulus guadalupensis*, and other land shells lived; and probably also the water of the lagoon, as it

¹⁶ The authority placed after these species (*Nob.*) is a contraction for *nobis* and means simply Purves.

dried up, became in places fresh, so that fresh-water forms could live in it and become mixed with the already deposited marine forms and the land forms. The wells near this St. George's locality show much sodium chloride in the water, as though it might have passed through a salt-pond stage. Such salt-pond deposits may have formed during the last stages of the rising of the island from the submergence at the time of the deposit of the shell layers in the Central Plain, already noted. Salt ponds now occur along the west coast of the island, but I did not personally observe them along the east coast; these "raised beaches" are probably such deposits in the limestone along the east coast. They are not likely to be of any great antiquity, and are not greatly different in their origin from what is now forming in the salt ponds of the western side of the island.

9. SALT POND AND MANGROVE SWAMP DEPOSITS.

As just noted above, these deposits are characteristic of certain places on the western shore line, from Corbizon Point to the vicinity of St. Mary's, Old Road. They are shallow bays that are gradually filling up. They are seen in all stages of development, for instance in the region of the head of Five Islands Bay and between this and St. John's Harbor. Salt pond deposits exist about a mile beyond the Union Sugar Mill. Evidently here a connection existed at no very distant time between Five Islands Bay and St. John's Harbor, and, indeed, upon Nugent's map this district is represented as a swamp. This same map shows a bay open to the sea east of the stretch of beach between Dry Hill and Corbizon Point, where a salt pond now exists; and open water on the north side of St. John's Harbor where a salt pond is now forming. Some ten such salt ponds are shown upon this Nugent map from Ships Stern (at the entrance of St. John's Harbor) to St. Mary's, Old Road. These shallow bays are first cut off from the sea by the growth of mangroves and such plants as can exist in presence of the salt water; a fringe of such mangroves near the mouth of the bay becomes a place for deposition of sand and other inorganic matter washed up by the waves, and a sand tract forms, cutting off the mouth of the bay. This bar gradually grows until the salt water only reaches in to the pond in time of high wind or tide. The water in the pond becomes brackish from the surface drainage getting into it, and the salt-water forms living in it, when freely open to the sea, are killed off, giving place to brackish-water and finally to fresh-water forms, if the pond continues to exist so long. When such a pond is near higher ground, the

washing from the hills carries land shells into the pond, and these are mingled with the salt-water and brackish-water forms. But in many cases, the swamp water becomes so foul during the change from salt to fresh that no brackish-water forms can live in it. Apparently, too, the change is rapid in some cases and no brackish-water forms migrate in. The shallow ponds become swamps and finally, draining to the sea, dry up completely and form level stretches which are occupied by the "bush," and eventually by cultivations of some kind. One such level stretch, formerly occupied, no doubt, by one of these salt pond swamps, is now under cultivation as a coconut plantation, near St. Mary's in the Valley.

Along the east coast such salt ponds were not visited, and perhaps they may no longer exist, but they are indicated on Nugent's map as occurring at several places along the northeast coast of the island. I have no doubt that the "horizontal marl" deposits in the vicinity of St. George's Church have had some such history; and if the general movement of the island is an upward one at present, as seems to be the case, other shallow bays such as are found along this east coast may develop into such salt ponds in the future. But the upward movement would seem to be more characteristic of the west coast than of the windward region, and the salt ponds of the west side of the island are now forming and show all stages of development. That such deposits must have occurred during the last emergence of the island and that traces of them are still to be seen in the interior (in the Central Plain, for instance) there can be little doubt. When they are very shallow and dry up when in the salt stage, leaving deposits of salt impregnating the surface soils, is probably indicated in the large amount of salt found in the shallow surface wells in some places at the present time. This salt impregnation of the soil in certain parts of the Central Plain has been noted under the "shell beds of the Central Plain." A local development of the same character, due to the accumulation of salt in hollows, subsequent to the last emergence of the island from the sea may be the cause of the "gall spots" noted in the cane cultivations in the Central Plain and eastward. These are places where the growth of the cane is poor, and they are generally marked by a yellowness of the cane itself. Mr. Tempany, Superintendent of Agriculture for the Leeward Islands, who has made many soil and water analyses, agrees with me that the gall spots are apparently places where soluble salts in the soil have accumulated to a point which interferes with the growth of the plants.

DESCRIPTIONS OF NEW SPECIES.

Helicina crosbyi n. sp. Plate XIX, figs. 1, 3, 8.

Helicina crosbyi Purves, Bull. Mus. Roy. Hist. Nat. Belg., Vol. III, 1884, p. 310. Name only. No description or figure.

Shell depressed, conic, of about four and one-half whorls, marked by growth-lines, periphery somewhat keeled up to the last whorl, where it becomes rounded. Outer lip much thickened and heavy, the inner lip expanding and covering the umbilicus with a heavy callus. The thickened outer lip rises abruptly from the last whorl in a ridge, which continues to beyond the columella and forms the border of the heavy callus of the inner lip, but this elevation of the lip dies away and the callus of the inner lip thins down until it reaches the level of the base of the last whorl. Slope of the spire even, the sutures not depressed, spire somewhat convex. Operculum unknown.

Alt. 7.7 mm., diam. 11 mm. Types A. N. S. P. Collection No. 109,109.

This species was named by Purves *H. crosbyi*, but apparently never described nor figured. It is easily identified as the species referred to by M. Purves, as it occurs fossil in the "horizontal marls" at several points noted by him, but is unknown in the living state and appears to be extinct. The "semi-fossil" shells are entirely without pigment, so that what colors the original shell possessed must remain unknown. The form of the heavy callus and the great thickening of the outer lip which characterize this species recall the lip and callus of the Jamaican *Helicina neritella angulata* C. B. Ad., which, however, differs from this species in having the angulation of the periphery continued on the last whorl out to the lip.

The specimens were collected at St. George's Church and at Hodge's Bay, Antigua. Pleistocene.

Scala (Sthenorhytis) antiguensis n. sp. Plate XX, fig. 9.

Shell turbate, of about five whorls, rapidly enlarging; the suture impressed, whorls rounded, crossed by about sixteen varices which are acute edged and rise abruptly from the whorl. The intervarical spaces are crossed by five raised revolving cords with a secondary sculpture of fine, somewhat irregularly spaced revolving lines and crossed by radial lines parallel to the varices. This secondary sculpture which covers the varices also, is best observed with a lens. From the excavated form of the base of the shell, it is probable that the mouth was circular, but this portion of the shell is imperfect. Alt. 30 mm., diam. 19 mm. From the Hodge's Hill limestone (Antigua formation), Hodge's Bay, Antigua. Oligocene.

Type A. N. S. P. Collection, invertebrate fossils, No. 1,645.

Turritella forresti n. sp. Plate XX, figs. 2, 3, 4, 7, 8.

Shell elongate, slowly tapering, of many whorls, with a raised sculpture of three major spiral ridges, of which the one towards the apex is double and beaded, the next one is at first single, but later becomes double and beaded, while the third is, in the younger stage, not beaded. Between these major revolving spiral ridges are finer revolving spirals, about five between the first and second major spirals, and the same number between the second and third major spirals, with a like number from the third spiral to the suture. These secondary spirals may become knotty and beaded when crossed by the diagonal growth lines, and the doubling of the major spirals comes from one of these minor spirals becoming enlarged on that side of the major spiral towards the apex. The suture becomes depressed by the shell being excavated above the suture or on the basal side of the whorl. A fragment of 14 mm. tapers from 4 mm. to 2 mm. in six whorls. A larger fragment tapers from 6 mm. to 4 mm. in a length of 13 mm.

From Willoughby Bay, collected by Mr. W. R. Forrest, in whose honor the species is named. Antigua limestone, Oligocene. Only small fragments were obtained, but these show the sculpture well and the species will undoubtedly be easily recognizable from these specimens. Types A. N. S. P. Collection, invertebrate fossils, No. 1,644.

Pecten (Amusium) antiguensis n. sp. Plate XVIII, figs. 1, 2, 3, 5.

Inequivalve, shell orbicular, rather thin, convex; the surface covered with a fine concentric sculpture, following the growth lines; with about 13 radial ribs running from the beaks, where they are very pronounced, and, in one valve, apparently disappearing towards the margin, but in the other valve continued as undulations of the shell to the margin. The interior of the shell has radial ribs extending to the margin, where the adjacent pairs of ribs contract and are then seen to be paired, but otherwise seeming to be equally spread as in *P. (Amusium) lyonii* Gabb, from which this species differs in having a strong concentric sculpture (wanting in *P. lyonii*), and also in the external radial ribbing being continued for a greater distance from the beak than in Gabb's species. The species is likewise related to *P. sol* B. and P., but this latter has shorter radial external ribs and the internal ribs are paired. The ears are separated from the rest of the valve by a depression, as is the case in *P. sol*. Length and height about equal—70-75 mm.

Hodge's Bay and Wetherill's Bay in the Antigua limestone, with

Orbitoides, etc., Oligocene. Cotypes A. N. S. P. Collection, invertebrate fossils, No. 1,648.

Pecten nugenti n. sp. • Plate XIX, figs. 2, 5, 6.

Shell inequivalve, oval in outline, with 17 distinct rounded radial ribs (and probably 2 additional less distinct ones) separated by narrower interspaces, the whole exterior surface covered by concentric growth lines which are raised and produce a nearly microscopic sculpture extending equally over ribs and interspaces. Internally smooth, except near the margin, where raised ribs are seen, occupying the intervals between the raised external ribs. On the flatter valve, externally the raised ribs are equal in width with the intervals between them, and the concentric sculpture, while extending over ribs and interspaces, is stronger in the intervals between the ribs. Ears moderate, apparently not ribbed. The specimens vary considerably in size; the one figured, a small specimen, measures: length 41 mm. by height 36 mm. Others were much larger, attaining a length of 55 mm. or more.

Named in honor of Dr. Christopher Nugent, the first to publish an account of the geology of Antigua. Collected at Hodge's Bay. Cotypes, A. N. S. P. Collection, invertebrate fossils, No. 1,656.

Ostrea antiguensis n. sp. Plate XIX, fig. 7; plate XX, figs. 1, 5, 6.

Shell ovate or nearly orbicular, thick and dense, externally radially plicate or sometimes nearly smooth, the plications on the lower, deep valve begin at the beak and are usually seven in number, of which a group of five ridges is separated from the other two by a broad depression; the ridges sharp and spinose or obtuse and even, the furrows or depressions smooth and rounded. Hinge moderate, the shell rapidly widening beyond the end of the hinge line, the plications usually dying away as the margin of the adult shell is reached, and this margin in the lower valve being turned up abruptly for one-half inch or more, making a cup-shaped valve. The upper or flat valve has the margin strongly reflexed to fit the upturned margin of the deep valve. The muscle impression is distinct, more strongly impressed in the case of the deep valve; situated on the left and nearer to the beak than to the opposite margin. The lower valve is more or less excavated internally, the upper valve is flat. When strongly plicate and even spinose, this species closely resembles *O. gatunensis* B. and P., except that this latter species has not the heavy shell of *O. antiguensis* nor has it the turned-up margin. *O. haitensis* Sowb. has the rugose exterior of this species in its strongly plicate

form, but while the shell is heavy, it lacks the upturned edge of *O. antiquensis*. Length 85 mm., alt. 80 mm., depth of lower valve 30 mm. Cotypes, A. N. S. P. Collection, invertebrate fossils, Nos. 1,653 and 1,655.

In size and plication *O. antiquensis* varies largely, but of the specimens collected the longest shells do not run far from 90 mm. in altitude. As regards plication, some are nearly smooth and some are strongly rugose, even in some cases spinose, but all may be distinguished by the broad furrow which runs across the exterior of the lower valve about opposite to the muscle impression and which divides the rugæ into a group of five and one of two. The species differs also from all other closely related American species by the upturned margin of this lower valve and the correspondingly reflexed margin of the upper or flat valve.

EXPLANATION OF PLATES XVIII, XIX, XX.

PLATE XVIII.—Fig. 1.—*Pecten (Amusium) antiquensis* n. sp. View of the exterior of a silicified specimen, showing some of the original shell surface. Natural size.

Fig. 2.—*Pecten (Amusium) antiquensis* n. sp. Interior view of shell. Natural size.

Fig. 3.—*Pecten (Amusium) antiquensis* n. sp. Exterior, showing hinge, of a non-silicified specimen, partly imbedded in the rock. Natural size.

Fig. 4.—*Pecten (Chlamys) anguillensis* Guppy. Exterior of a silicified specimen, in which the original surface was destroyed by the silicification. Natural size.

Fig. 5.—*Pecten (Amusium) antiquensis* n. sp. Detail of a portion of specimen 1. $\times 3$.

Fig. 6.—*Pecten (Chlamys) anguillensis* Guppy. Exterior of an unsilicified specimen, showing the distinctive secondary ribbing. Natural size.

Fig. 7.—*Pecten (Chlamys) anguillensis* Guppy. Interior of valve. Natural size.

Fig. 8.—*Pecten (Chlamys) anguillensis* Guppy. Exterior of a silicified specimen, showing traces of the secondary ribbing. Natural size.

PLATE XIX.—Fig. 1.—*Helicina crosbyi* n. sp. Mouth view of a specimen. $\times 2$.

Fig. 2.—*Pecten nugenti* n. sp. Interior view of the shell, showing the hinge. Figure slightly above natural size.

Fig. 3.—*Helicina crosbyi* n. sp. Under side of shell, showing the heavy umbilical callus and thickened lip. $\times 2$.

Fig. 4.—*Orbitoides mantelli* Mort. The figure shows a fragment of the rock with two specimens of this large species. About natural size.

Fig. 5.—*Pecten nugenti* n. sp. Exterior aspect of the deeper valve. Very slightly enlarged.

Fig. 6.—*Pecten nugenti* n. sp. Enlarged view of a fragment of the exterior of the shell, showing the concentric secondary sculpture. $\times 3$.

Fig. 7.—*Ostrea antiquensis* n. sp. Interior of shell, showing muscle impression and hinge. Natural size.

Fig. 8.—*Helicina crosbyi* n. sp. Lateral view of shell, showing the raised and thickened outer part of the lip. $\times 2$.

PLATE XX.—Fig. 1.—*Ostrea antiquensis* n. sp. Exterior of the deep valve of a nearly smooth specimen. The figure is slightly above the natural size.

Figs. 2-4.—*Tarritella forresti* n. sp. $\times 3$.

- Fig 5.—*Ostrea antiquensis* n. sp. Exterior of the deep valve of a rugose specimen. Slightly enlarged above natural size.
- Fig. 6.—*Ostrea antiquensis* n. sp. Interior of the flat valve, partly imbedded in the limestone. This specimen shows the strongly reflexed margin of this valve. The concentric markings are due to partial silicification.
- Figs. 7, 8.—*Turritella forresti* n. sp. $\times 3$.
- Fig. 9.—*Scala (Sthenorhytis) antiquensis* n. sp. Natural size.